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Approximate Spring Balancing for Swimming Pool Lift Mechanism to Reduce Actuator Torque

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Abstract : Reducing actuator loads is important for applications in which human effort is required for actuation. The potential benefit of applying spring balancing to rehabilitation devices which work against gravity on a nonhorizontal plane is well recognized, but practical applications have been elusive. Although existing methods provide exact spring balance, they require additional masses or auxiliary links, or all the springs used originate from the ground, which makes the resulting device bulky and space-inefficient. This paper uses a method of static balancing of mechanisms with conservative loads such as gravity and spring loads using non-zero-free-length springs and no auxiliary links. Application of this method to a manually operated swimming pool lift mechanism which lowers and raises the physically challenged users into or out of the swimming pool is presented here. Various possible configurations using extension and compression springs as well as gas spring in the mechanism are compared. This work involves approximate spring balancing of the mechanism using minimization of potential energy variance. It uses the approach of flattening the potential energy distribution over the workspace and fuses it with numerical optimization. The results show the considerable reduction in actuator torque requirement with practical spring design and arrangement. Although the method provides only an approximate balancing, it is versatile, flexible in choosing appropriate control variables that are relevant to the design problem and easy to implement. The true potential of this technique lies in the fact that it uses a very simple optimization to find the spring constant, free length of the spring and the optimal attachment points subject to the optimization constraints. Also, it uses physically realizable non-zero-free-length springs directly, thereby reducing the complexity involved in simulating zero-free-length springs from non-zero-free-length springs. This method allows springs to be attached inside the mechanism, which makes the implementation of spring balancing practical. Because auxiliary linkages can be avoided, the resultant swimming pool lift mechanism is compact. The cost benefits and reduced complexity can be significant advantages in the development of this user-actuated swimming pool lift for developing countries.

Keywords : gas spring, rehabilitation device, spring balancing, swimming pool lift
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